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Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number:

0 302 371
A2

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 88112103.2

(51) Int. Cl.4: **C07D 401/04 , C07D 471/04 ,**
A61K 31/435 , A61K 31/47 ,
/(C07D471/04,221:00,221:00)

(22) Date of filing: 27.07.88

(30) Priority: **04.08.87 US 81416**
26.02.88 US 160950

(43) Date of publication of application:
08.02.89 Bulletin 89/06

(84) Designated Contracting States:
AT BE CH DE ES FR GB GR IT LI LU NL SE

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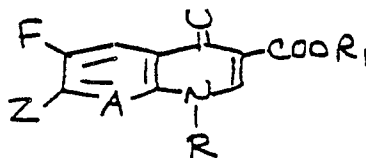
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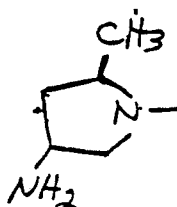
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(54) **7-(2-Methyl-4-aminopyrrolidinyl)naphthyridine and quinoline compounds.**

(57) Naphthyridine and quinoline compounds having the formula:



wherein A is CH or N; Z is an amine having the formula:



R is o,p-difluorophenyl or p-fluorophenyl; and R₁ is hydrogen or a carboxy protecting group. The compounds of the invention have antibacterial activity and improved solubility and pharmacokinetic properties.

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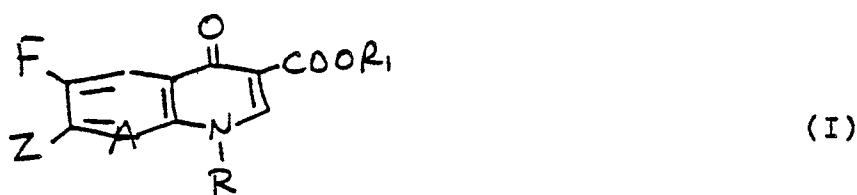
7-(2-METHYL-4-AMINOPYRROLIDINYL) NAPHTHYRIDINE AND QUINOLINE COMPOUNDS

This is a continuation-in-part of copending U.S. patent application, Serial No. 784,421, filed October 4, 1985, which is a continuation of Serial No. 597,854 filed April 9, 1984, which is a continuation-in-part of Serial No. 574,227, filed January 26, 1984, which is a continuation-in-part of Serial No. 514,716, filed July 18, 1983.

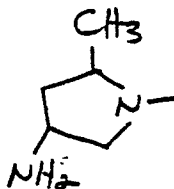
This invention relates to new naphthyridine and quinoline derivatives having antibacterial properties, compositions containing the new naphthyridine and quinoline derivatives and methods of treating mammalian patients with the new naphthyridine and quinoline derivatives.

It is known that certain naphthyridine and quinoline compounds exhibit antibacterial properties, notably certain 7-piperazinyl-4-oxo-1,8-naphthyridine-3-carboxylic acids. In European Patent No. 9,425, there are disclosed certain 7-piperazinyl-6-fluoro-1, 4-dihydro-4-oxo-1,8-naphthyridine-3-carboxylic acid derivatives which are substituted in the 1 position with an alkyl or vinyl substituent.

This invention relates to novel antibacterial agents and, more particularly, to 7-substituted 6-fluoro-1,4-dihydro-4-oxo-1,8-naphthyridine and quinoline-3-carboxylic acids and derivatives thereof having the formula:



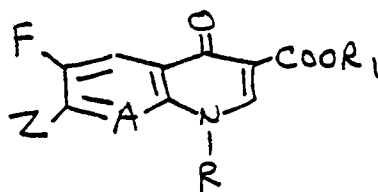
wherein A is CH or N, R is p-fluorophenyl (1) or o,p-difluorophenyl, R₁ is hydrogen or a carboxy-protecting group and Z is the structure having the formula:



The compounds of this invention have substantially improved solubility properties relative to those lacking the 2-substituent on the pyrrolidine ring (Table 3); however they still maintain extremely potent antibacterial activity (Tables 1 and 2). The improvement in solubility greatly reduces the probability of crystalluria that is associated with compounds possessing low solubility at physiological pH. The increased solubility also eases in the preparation of i.v. formulations of these drugs. The improved solubility properties of these agents have also resulted in greatly improved oral absorption and pharmacokinetic properties (Table 4).

As used herein, the term "carboxy-protecting group" refers to and includes the residue of a carboxylic acid ester group. Such carboxy-protecting groups are well known to those skilled in the art, having been extensively used in the protection of carboxyl groups in the penicillin and cephalosporin fields, as described in U.S. Patent Nos. 3,840,556 and 3,719,667, the disclosures of which are incorporated herein by reference. In general, such carboxy-protecting groups can be relatively easily cleaved to yield the corresponding free carboxy group. Representative protecting groups include C₁ to C₈ alkyl (e.g., methyl, ethyl, tertiary butyl), benzyl and substituted derivatives thereof such as alkoxy and nitrobenzyl groups; also suitable are acyloxyalkyl groups such as a pivaloyloxymethyl group.

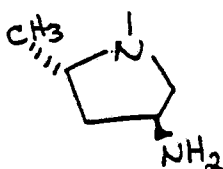
The preferred compounds of the invention are those having the formula:



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wherein R is as described above and is preferably *o,p*-difluorophenyl, R₁ is as described above and is preferably hydrogen, A is as described above and Z is as described above preferably having the formula:

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wherein the absolute stereoconfiguration of the 2-methyl substituent is S and the absolute stereoconfiguration of the 4-amino substituent is S.

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Also included within the scope of the present invention are pharmaceutically acceptable salts of the foregoing compounds. As used herein, the term "pharmaceutically acceptable salts" refers to non toxic acid addition salts and alkaline earth metal salts of the compounds of formula 1. The salts can be prepared in situ during the final isolation and purification of the compounds of formula 1, or separately by reacting the free base or acid functions with a suitable organic acid or base. Representative acid addition salts include the hydrochloride, hydrobromide, sulphate, bisulphate, acetate, oxalate, valerate, oleate, palmitate, stearate, laurate, borate, benzoate, lactate, phosphate, tosylate, mesylate, citrate, maleate, fumarate, succinate, tartrate, glucoheptonate, lactobionate, lauryl sulfate salts and the like. Representative alkali or alkaline earth metal salts include the sodium, calcium, potassium and magnesium salts, etc.

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It has been found that the compounds of the present invention possess antibacterial activity against a wide spectrum of gram positive and gram negative bacteria, as well as enterobacteria and anaerobes. The compounds of the invention are therefore useful in the antibiotic treatment of susceptible bacterial infections in both humans and animals. In addition, the compounds, by reason of their in vitro activity, may be used in scrub solutions for surface inhibition of bacterial growth.

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Susceptible organisms generally include those gram positive and gram negative, aerobic and anaerobic organisms whose growth can be inhibited by the compounds of the invention such as Staphylococcus, Lactobacillus, Streptococcus, Sarcina, Escherichia, Enterobacter, Klebsiella, Pseudomonas, Acinetobacter, Proteus, Campylobacter, Citrobacter, Nisseria, Bacillus, Bacteroides, Peptococcus, Clostridium, Salmonella, Shigella, Serratia, Haemophilus, Brucella and other organisms. In addition to exhibiting highly effective antibacterial activity, the compounds of the invention exhibit increased and improved solubility characteristics and oral absorption properties as compared with prior art naphthyridine-3-carboxylic acid compounds.

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The compounds of formula 1 may also be formulated into compositions together with pharmaceutically acceptable carriers for parenteral injection, for oral administration in solid or liquid form, for rectal administration, and the like.

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Compositions according to the invention for parenteral injection may comprise pharmaceutically acceptable sterile aqueous or nonaqueous solutions, suspensions or emulsions. Examples of suitable nonaqueous carriers, diluents, solvents or vehicles include propylene glycol, polyethylene glycol, vegetable oils, such as olive oil, and injectable organic esters such as ethyl oleate. Such compositions may also contain adjuvants such as preserving, wetting, emulsifying, and dispersing agents. They may be sterilized, for example, by filtration through a bacteria-retaining filter, or by incorporating sterilizing agents into the compositions. They can also be manufactured in the form of sterile solid compositions which can be dissolved in sterile water, or some other sterile injectable medium immediately before use.

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Solid dosage forms for oral administration include capsules, tablets, pills, powders and granules. In such solid dosage forms, the active compound is admixed with at least one inert diluent such as sucrose, lactose or starch. Such dosage forms can also comprise, as is normal practice, additional substances other than diluents, e.g., lubricating agents such as magnesium stearate. In the case of capsules, tablets and pills, the dosage forms may also comprise buffering agents. Tablets and pills can additionally be prepared with enteric coatings.

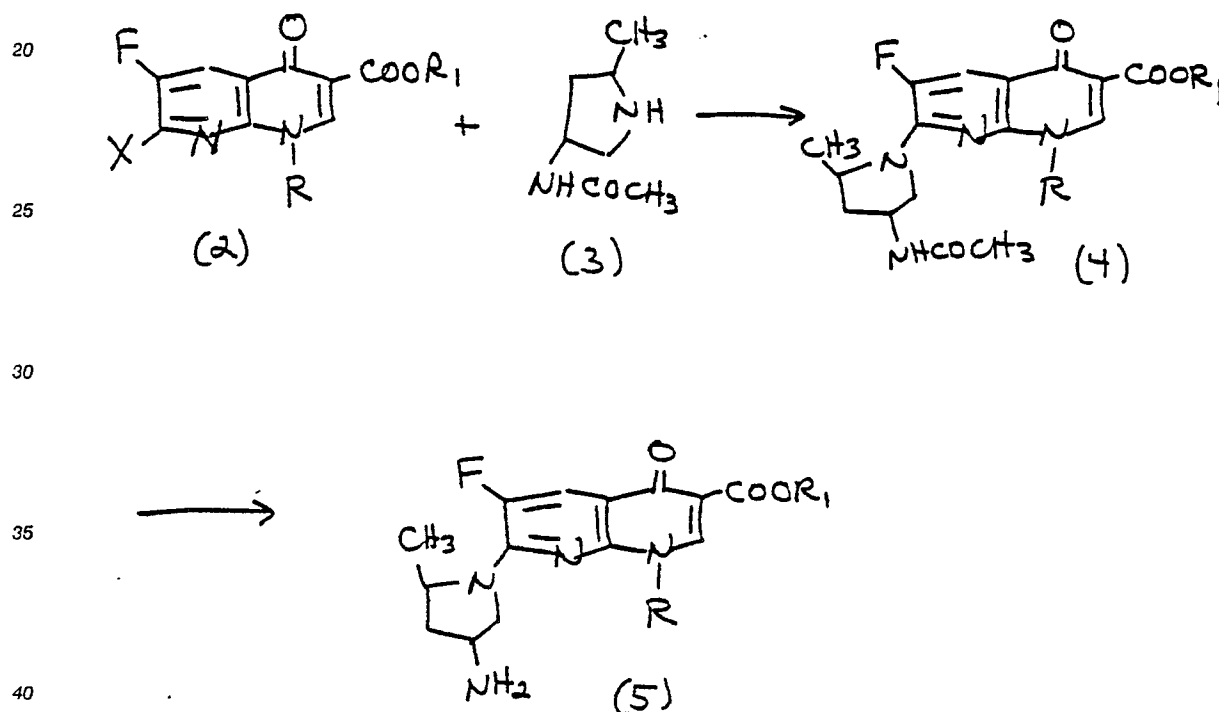
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Liquid dosage forms for oral administration include pharmaceutically acceptable emulsions, solutions, suspensions, syrups and elixers containing inert diluents commonly used in the art, such as water. Besides such inert diluents, compositions can also include adjuvants, such as wetting agents, emulsifying and suspending agents, and sweetening, flavoring and perfuming agents.

Compositions for rectal administration are preferably suppositories which may contain, in addition to the active substance, excipients such as coco butter or a suppository wax.

Actual dosage levels of active ingredient in the compositions of the invention may be varied so as to obtain an amount of active ingredient effective to achieve antibacterial activity in accordance with the desired method of administration. The selected dosage level therefore depends upon the nature of the active compound administered, the route of administration, the desired duration of treatment and other factors. Generally, daily dosage levels of the compounds of Formula 1 of about 0.1 to about 750, more preferably about 0.25 to about 500 and most preferably about 0.5 to about 300 mg. of active ingredient per kg. of body weight are effective when administered orally to a mammalian patient suffering from an infection caused by a susceptible organism. If desired, the daily dose may be divided into multiple doses for administration, e.g., two or four times per day.

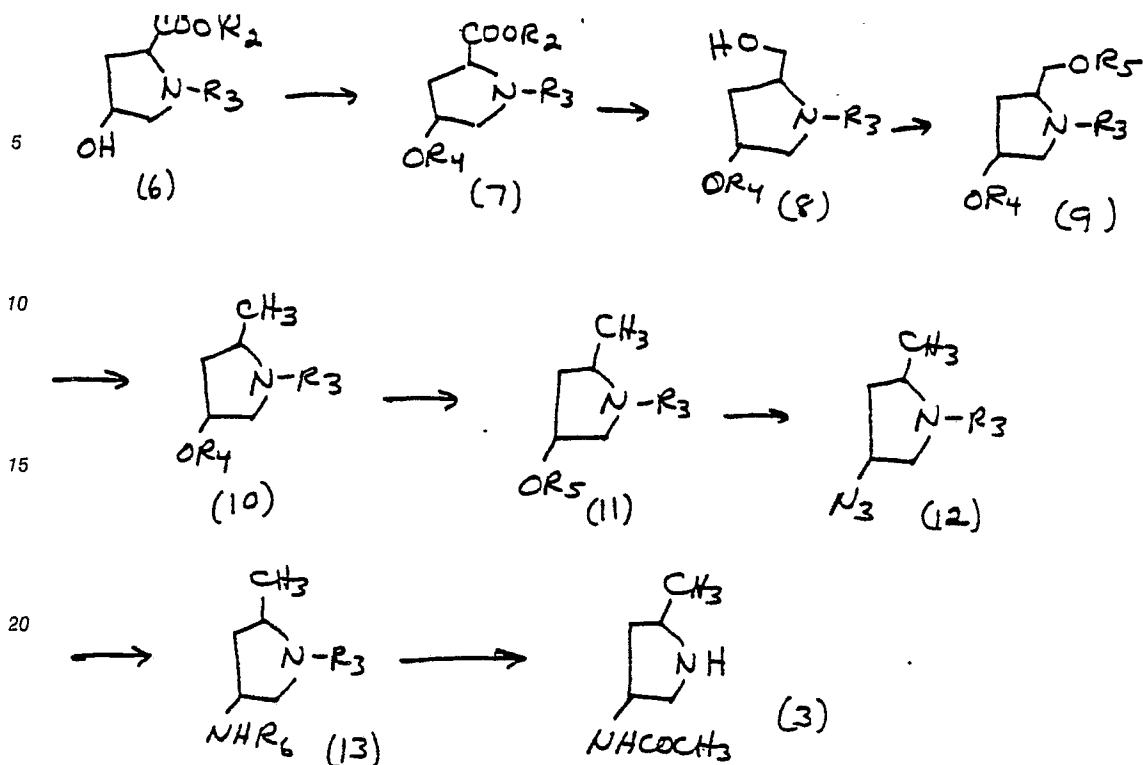
The naphthyridine compounds according to this invention can be prepared by the reaction sequence illustrated below:



wherein X is a halogen, mesylate or methoxy group and R and R₁ are the same as described above.

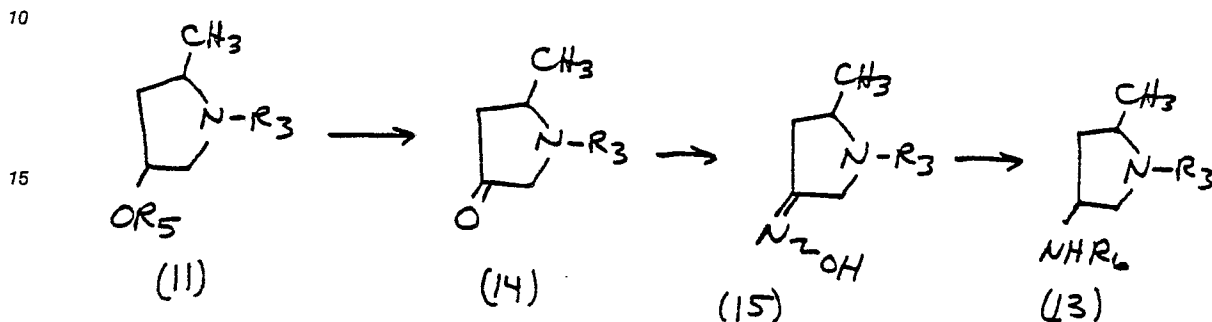
Heating a compound of the formula (2) with an amine of formula (3) at a temperature of from 20° C to 150° C, in the presence of a suitable organic polar or non-polar solvent such as dimethylsulfoxide, sulfolane, dimethylformamide (DMF), dimethylacetamide, 1-methyl-2-pyrrolidinone, pyridine, water, tetrahydrofuran (THF) or methylene chloride provides compound (4). It is desirable to carry out the reaction in the presence of an acid-acceptor such as triethylamine, potassium carbonate or the like at a molar ratio of 1.0 to 2.0 moles of the acid-acceptor per mole of the compound of the formula (2). The amine (3) can also be used as acid acceptor in which 2 or more molar excess of this reagent is used. The ester in (4) is hydrolyzed by treatment with dilute sodium hydroxide in aqueous THF. Subsequent hydrolysis of the N-acetyl group with hydrochloric acid furnishes the naphthyridine (5) (R₁ = H). The compounds of the formula (2) may be prepared in accordance with the prior art (U.S. Patent No. 4,616,019).

Amines of the formula (3) may be prepared in accordance with the following reaction scheme.



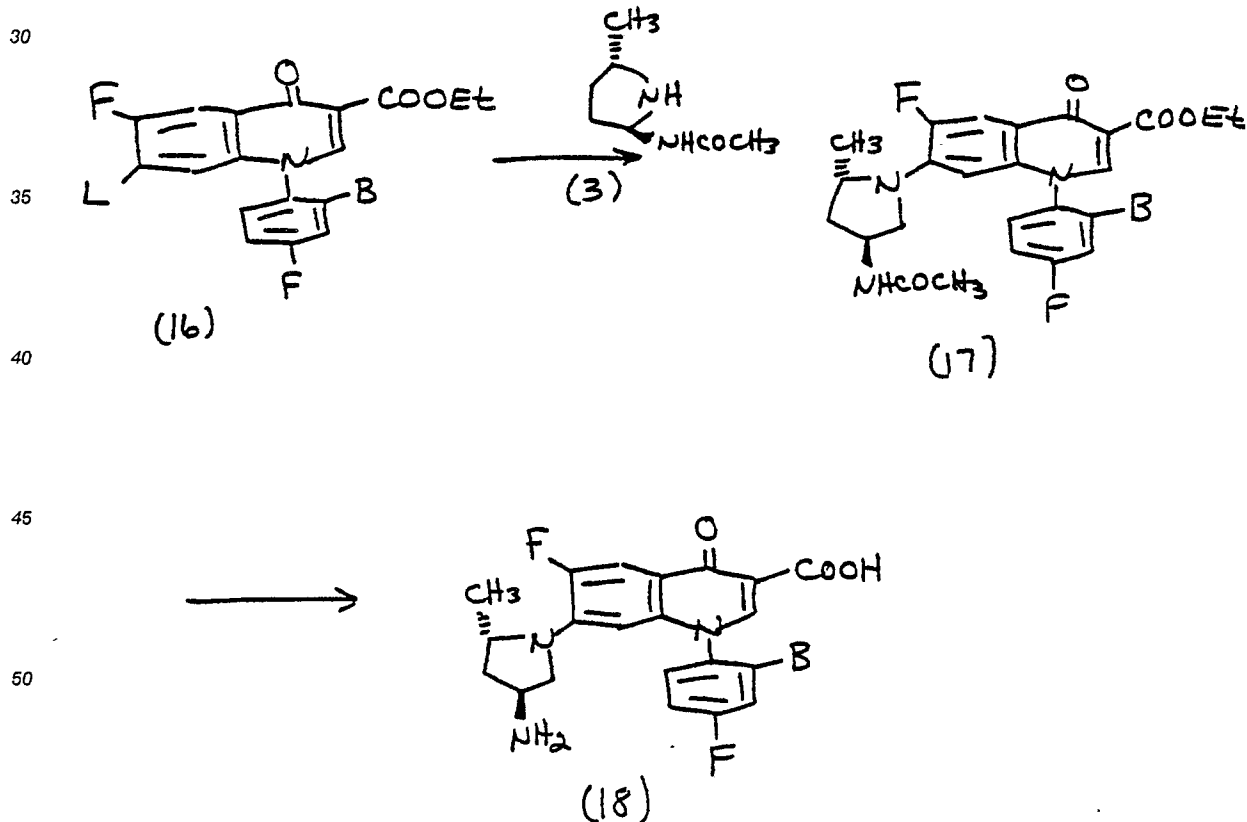
The known hydroxyproline (6) ($R_2 = R_3 = H$) is first converted to its corresponding alkyl, aryl or arylalkyl ester, preferably its methylester, upon refluxing in methanol containing HCL. The ester (6) ($R_2 = CH_3, R_3 = H$) may be isolated as its hydrochloride salt. Protection of the amine function by conversion to a suitable carbamate or amide derivative, preferably using the *tert*-butoxycarbonyl group by treatment of (6) ($R_2 = CH_3, R_3 = H$) with di-*tert*-butyl dicarbonate in the presence of a base such as triethylamine in a solvent such as dichloromethane or THF provides at a temperature of about $-10^\circ C$ to $25^\circ C$ (6) ($R_2 = CH_3, R_3 = -COO^tBu$). Protection of the secondary hydroxyl group with a suitable alkyl, alkoxyalkyl or silyl ether, preferably the *tert*-butyldimethylsilyl group by treatment of (6) ($R_2 = CH_3, R_3 = -COO^tBu$) with *tert*-butylchlorodimethylsilane in the presence of a base such as imidazole, triethylamine or pyridine in a suitable solvent such as dichloromethane, THF or *N,N*-dimethylformamide (DMF) at a temperature of about $0^\circ C$ to $60^\circ C$ furnishes compound (7) ($R_2 = CH_3, R_3 = -COO^tBu, R_4 = ^tBuSi(CH_3)_2$). The ester group in (7) is reduced with an appropriate hydride reagent such as lithium borohydride in a solvent such as THF or dimethoxyethane at a temperature of about $-20^\circ C$ to $25^\circ C$ to afford the corresponding primary alcohol (8). The primary alcohol in (8) is converted to a good leaving group such as *p*-toluenesulfonyloxy, trifluoromethanesulfonyloxy or preferably methanesulfonyloxy upon treatment with methanesulfonyl chloride in the presence of a base such as triethylamine in a solvent such as THF or preferably dichloromethane at a temperature of about $-10^\circ C$ to $30^\circ C$ to obtain (9) ($R_5 = SO_2CH_3$). Deoxygenation of (9) is accomplished by treatment with a good source of nucleophilic hydride, preferably lithium triethylborohydride, in a solvent such as DMF or preferably THF at a temperature of about $25^\circ C$ to obtain (10). Cleavage of the hydroxyl protecting group in (10) using an acid such as hydrofluoric acid, hydrobromic acid or hydrochloric acid or a base such as sodium hydroxide in aqueous THF or a source of fluoride ion such as cesium fluoride, potassium fluoride or preferably tetra-*n*-butylammonium fluoride in the preferential case where $R_5 = ^tBuSi(CH_3)_2$ in a solvent such as THF, methanol or acetonitrile gives the alcohol (11) ($R_5 = H$). Activation of the hydroxyl group in (11) by conversion to a leaving group such as *p*-toluenesulfonyloxy, trifluoromethanesulfonyloxy or preferably methanesulfonyloxy by treatment with methanesulfonyl chloride in the presence of a base such as triethylamine or pyridine in a solvent such as dichloromethane or THF at a temperature of about $0^\circ C$ to $40^\circ C$ furnishes (11) ($R = SO_2CH_3$). Displacement of the leaving group in (11) with a source of azide such as lithium azide, sodium azide or preferably tetra-*n*-butylammonium azide in a solvent such as acetonitrile at a temperature of about $30^\circ C$ to $80^\circ C$ gives (12). Reduction of the azide group with a hydride reagent such as lithium borohydride or sodium borohydride or preferably with hydrogen in the presence of a suitable catalyst in a solvent such as methanol at a temperature of about $25^\circ C$ affords the corresponding amine (13) ($R_6 = H$) which is acetylated with acetic anhydride in the presence of a base such as triethylamine in a

solvent such as pyridine or dichloromethane at a temperature of about -15°C to 40°C to afford the N-acetyl derivative (13) ($R_6 = -\text{COCH}_3$). Alternatively, (12) can be converted directly to (13) ($R_6 = -\text{COCH}_3$) upon treatment with thiolacetic acid. The nitrogen-protecting group R_3 is removed to give (13). In the preferable case where $R_3 = \text{COO}^t\text{Bu}$, this transformation is accomplished by treatment of (13) with an acid, preferably trifluoroacetic acid at temperature of about -20°C to 40°C . Compound (13) may be isolated as its trifluoroacetic acid salt, or alternatively the salt may be dissolved in a solvent such as methanol or dichloromethane and treated with a basic exchange resin. Filtration of the resin followed by concentration of the filtrate affords the base (13). Alternatively, compound (11) ($R_5 = \text{H}$) may be transformed to (13) ($R_6 = \text{H}$) by the method shown below.



Oxidation of (11) ($R_5 = \text{H}$), preferably employing the Swern protocol ($\text{DMSO}, (\text{ClCO})_2, \text{CH}_2\text{Cl}_2, \text{Et}_3\text{N}$) provides the ketone (14). Treatment of (14) with hydroxylamine provides the corresponding oxime (15) which is reduced by hydrogen in the presence of a suitable catalyst such as Raney Nickel in a solvent such as methanol to afford the amine (13) ($R_6 = \text{H}$).

The quinoline compounds according to this invention can be prepared by the reaction sequence illustrated below:



wherein B is hydrogen or fluoro and L is Cl or F.

Heating a compound (16) with an amine of compound (3) at a temperature of from 20° C to 150° C, in the presence of a suitable organic polar or non-polar solvent such as dimethylsulfoxide, sulfolane, dimethylformamide (DMF), dimethylacetamide, 1-methy-2-pyrrolidinone, pyridine, water, tetrahydrofuran (THF) or methylene chloride provides compound (17). It is desirable to carry out the reaction in the presence of an acid-acceptor such as triethylamine, potassium carbonate or the like at a molar ratio of 1.0 to 2.0 moles of the acid-acceptor per mole of the compound (16). The amine (3) can also be used as acid acceptor in which 2 or more molar excess of this reagent is used. The ester in (17) is hydrolyzed by treatment with dilute sodium hydroxide in aqueous THF. Subsequent hydrolysis of the N-acetyl group with hydrochloric acid furnishes the quinoline (18) ($R_1 = H$). The compounds (16) may be prepared in accordance with the prior art (D. Chu et al., Journal of Medicinal Chemistry, 1985, Vol. 28, 1558; D. Chu et al. 26th Interscience Conference on Antimicrobial Agents and Chemotherapy, September 28 - October 1, 1986; New Orleans, LA, Abstract #428).

The foregoing may be better understood from the following examples, which are presented for purposes of illustration and are not intended to limit the scope of the inventive concepts. As used in the following examples, the references to compounds, such as (1), (2), (3), etc., and to substituents, such as R, R_1 , R_2 , etc., refer to the corresponding compounds and substituents in the foregoing reaction scheme and formulae.

Example 1

(2S,4S)-4-Acetamido-2-methylpyrrolidine

(a) In a 2l round-bottom flask was placed 400 mL of methanol, and the system was cooled in an ice bath. To the system at ice temperature was added 50.3g (45.6mL, 0.64 mol) of acetyl chloride dropwise through an addition funnel, followed by the addition of 60g (0.46 mol) of 4-hydroxyproline. The reaction mixture was heated at reflux under nitrogen for 8h and cooled to room temperature. Ether was added to the system, and the resulting white precipitate ((2R,4R)-(6)($R_2 = CH_3, R_3 = H$)).HCL, 84g, quantitative yield) was collected by suction filtration, mp 121-123° C.

(b) In a 2l round-bottom flask were placed 98g (0.54 mol) of (2R,4R)-(6)($R_2 = CH_3, R_3 = H$)).HCL and 650 mL of dichloromethane. To this suspension was added 164g (220 mL, 1.72 mol) of triethylamine, and the system was immersed in an ice-salt bath. To the system was added 130g (0.59 mol) of di-tert-butyl dicarbonate, and the reaction mixture was stirred under nitrogen for 12h, during which time the ice bath expired. The reaction mixture was washed with 1M aqueous phosphoric acid and saturated aqueous sodium bicarbonate, dried (Na_2SO_4) and concentrated with a rotary evaporator. The resulting yellow oil was crystallized from hexanes to obtain 118g (90% yield) of pure (2R,4R)-(6)($R_2 = CH_3, R_3 = -COO^tBu$) as a white solid, mp 74-77° C.

(c) In a 2l round-bottom flask were placed 118g (0.48 mol) of (2R,4R)-(6)($R_2 = CH_3, R_3 = -COO^tBu$) and 150 mL of DMF. To this stirring solution were added 68.1g (1.0 mol) of imidazole and 80.1g (0.53 mol) of tert-butylchlorodimethylsilane. The reaction mixture was stirred at room temperature under nitrogen for 1.5h, diluted with ether and washed with water, 1M aqueous phosphoric acid and saturated aqueous sodium bicarbonate. The ether solution was dried (Na_2SO_4) and concentrated with a rotary evaporator to obtain 172g (99% yield) of (2R,4R)-(7)($R_2 = CH_3, R_3 = -COO^tBu, R_4 = -Si^tBu(CH_3)_2$) as a clear colorless oil.

(d) In a 3l 3-neck round-bottom flask were placed 169g (0.47 mol) of (2R,4R)-(7)($R_2 = CH_3, R_3 = -COO^tBu, R_4 = -Si^tBu(CH_3)_2$) and 300 mL of THF. The system was placed under a nitrogen atmosphere and cooled in an ice-salt bath. To this stirring solution was added 15.6g (0.72 mol) of lithium borohydride in 150 mL of THF dropwise through an addition funnel. The reaction mixture was stirred for 16h, during which time the ice bath expired. The reaction mixture was diluted with ethyl acetate, and ice was added to the system. After the ice melted, the layers were separated. To the organic phase was cautiously (exothermic) added 1M aqueous phosphoric acid. The layers were separated, and the organic phase was washed with saturated aqueous sodium bicarbonate and brine, dried (Na_2SO_4) and concentrated with a rotary evaporator to afford 146g (93% yield) of (2R,4R)-(8)($R_3 = -COO^tBu, R_4 = -Si^tBu(CH_3)_2$) as a clear colorless oil.

(e) In a 1 liter round-bottom flask were placed 140g (0.42 mmol) of (2R,4R)-(8)($R_3 = -COO^tBu, R_4 = -Si^tBu(CH_3)_2$) and 130 mL of dichloromethane. To the system was added 85.4g (118 mL, 0.85 mol) of

triethylamine. The system was cooled in an ice-salt bath, and 72.6g (50 mL, 0.63 mol) of methanesulfonyl chloride was added to the mixture through an addition funnel. The reaction mixture was stirred under nitrogen for 15h, during which time the ice bath expired. The reaction mixture was partitioned between ethyl acetate and water. The ethyl acetate solution was washed with 1M aqueous phosphoric acid and saturated aqueous sodium bicarbonate, dried (Na_2SO_4) and concentrated with a rotary evaporator to obtain 162g (94% yield) of $(2R,4R)-(9)(R_3 = -\text{COO}^t\text{Bu}, R_4 = -\text{Si}^t\text{Bu}, (\text{CH}_3)_2R_5 = -\text{SO}_2\text{CH}_3)$ as a viscous yellow oil.

(f) Under a nitrogen atmosphere, in a 3 liter 3-neck round-bottom flask were placed 80g (0.20 mol) of $(2R,4R)-(9)(R_3 = -\text{COO}^t\text{Bu}, R_4 = -\text{Si}^t\text{Bu}, (\text{CH}_3)_2R_5 = -\text{SO}_2\text{CH}_3)$ and 120 mL of THF. The system was cooled in an ice bath and 800 mL (0.80 mol) of 1M lithium triethylborohydride in THF was added to the system through an addition funnel. The cold bath was removed, and the reaction mixture was stirred at room temperature for 2h. The mixture was diluted with ethyl acetate and washed with water, 1M aqueous phosphoric acid, saturated aqueous sodium bicarbonate and brine. The ethyl acetate solution was dried (Na_2SO_4) and concentrated with a rotary evaporator. The resulting oil was diluted with ethyl acetate, solids were removed by suction filtration and the filtrate was concentrated to obtain 59g of clear yellow oil. This procedure was repeated on the same scale to afford 64g of additional product. The crude material was combined and used without further purification. The oil from above was placed in a 1 liter round-bottom flask. To the system was added 430 mL (0.43 mol) of 1M tetra-n-butylammonium fluoride in THF. This solution was stirred under nitrogen for 2.5h, diluted with 800 mL of ethyl acetate and washed with three 300 mL portions of water. The combined aqueous washings were extracted with four 100 mL portions of ethyl acetate. The combined organic fractions were dried (Na_2SO_4) and concentrated with a rotary evaporator to afford 117g of yellow oil. The crude product was purified by flash column chromatography using 1:2 ethyl acetate/hexanes as the eluant to obtain 49.6g (63% yield) of pure $(2S,4R)-(11)(R_3 = -\text{COO}^t\text{Bu}, R_5 = \text{H})$ as a white solid, mp 75-78 °C.

(g) In a 1 liter round-bottom flask were placed 18.3g (91 mmol) of $(2S,4R)-(11)(R_3 = -\text{COO}^t\text{Bu}, R_5 = \text{H})$, 30 mL of dichloromethane and 23g (32 mL, 0.23 mol) of triethylamine. The system was cooled in an ice bath. To the system was slowly added 20.8g (14.4 mL, 182 mmol) of methanesulfonyl chloride. The reaction mixture was stirred under nitrogen for approximately 14h, during which time the ice bath expired. The reaction mixture was diluted with ether, washed with 1M aqueous phosphoric acid and saturated aqueous sodium bicarbonate, dried (Na_2SO_4) and concentrated with a rotary evaporator to obtain 24.1g of light red oil. This material was subjected to flash column chromatography using 1:1 ethyl acetate/hexanes as the eluant to obtain 16.1g of oil. This oil was placed in a 1 liter round-bottom flask and dissolved in 25 mL of acetonitrile. To this solution was added 18.1g (63.5 mmol) of tetra-n-butylammonium azide, and the mixture was heated at 65 °C for 3h under nitrogen. The reaction mixture was diluted with ether, and the upper ether layer was washed with two 100 mL portions of saturated aqueous sodium bicarbonate and brine. The combined aqueous washings and initial lower layer were extracted with three 100 mL portions of ether. The combined organic fractions were dried (Na_2SO_4) and concentrated with a rotary evaporator.

The crude material was purified by flash column chromatography using 1:1 ethyl acetate/hexanes as the eluant to obtain 8.75g (43% yield) of pure $(2S,4S)-(12)(R_3 = -\text{COO}^t\text{Bu})$ as an oil.

(h) A solution of 8.86g (39.2 mmol) of $(2S,4S)-(12)(R_3 = -\text{COO}^t\text{Bu})$ in 250 mL of methanol containing 4.2g of 10% palladium on carbon was placed under 4 atm of hydrogen. After 1h, the catalyst was removed by filtration through celite and the filtrate was concentrated with a rotary evaporator. In a 500 mL round-bottom flask were placed the crude amine $(2S,4S)-(13)(R_3 = -\text{COO}^t\text{Bu}, R_6 = \text{H})$ and 13 mL of pyridine. To the system was added 8.0g (11.1 mL, 79.5 mmol) of triethylamine, and the system was cooled in an ice bath. To the system was added 8.1g (7.5 mL, 79.5 mmol) of acetic anhydride, and the solution was stirred for 19h at room temperature under nitrogen. The reaction mixture was diluted with chloroform and washed with 10% aqueous hydrochloric acid, saturated aqueous sodium bicarbonate and brine. The chloroform solution was dried (Na_2SO_4) and concentrated with a rotary evaporator to obtain 7.47g of $(2S,4S)-(13)(R_3 = -\text{COO}^t\text{Bu}, R_6 = -\text{COCH}_3)$ as a red/brown gummy solid which was used in subsequent transformations without further purification. The purified acetamide (pale yellow solid) melts at 107-110 °C.

(i) In a 50 mL round-bottom flask were placed 3.1g (13 mmol) of the crude $(2S,4S)-(13)(R_3 = -\text{COO}^t\text{Bu}, R_6 = -\text{COCH}_3)$ prepared in Example 1(h) and 15g (10 mL, 130 mmol) of trifluoroacetic acid. The solution was stirred under nitrogen for 15 min. and concentrated with a rotary evaporator. The residue was dissolved in 75 of methanol. To this solution was added 30g of Rexyn 201(OH) resin which had been rinsed with ethanol. The mixture was stirred under nitrogen for 15 min., and 10g of additional resin was added to the mixture. The resin was removed by filtration through celite, and the filtrate was concentrated with a rotary evaporator to obtain 2g of crude $(2S,4S)-(3)$ which was used immediately for Example 2.

Example 2(2',4'S)-7-(4'-Amino-2'-methylpyrrolidin-1'-yl)-1-(o,p-difluorophenyl)-1,4-dihydro-6-fluoro-4-oxo-1,8-naphthyridine-3-Carboxylic Acid

(a) In a 100 mL round-bottom flask were placed the crude (2',4'S)-(3) prepared in Example 1(i) and 6 mL of pyridine. To the system were added 1.4g (2 mL, 13.9 mmol) of triethylamine and 5.5g (14 mmol) of (2) (x = Cl, R = o,p-difluorophenyl, R₁ = -CH₂CH₃). The reaction mixture was heated at 65 °C for 14h under nitrogen, and the solvent was removed with a rotary evaporator. The crude material was purified by flash column chromatography to obtain 4.9g (78% yield) of (2',4'S)-(4)(R = o,p-difluorophenyl, R₁ = -CH₂CH₃).

(b) In a 1 liter round-bottom flask were placed 4.9g (10 mmol) of (2',4'S)-4(R = o,p-difluorophenyl, R₁ = -CH₂CH₃) and 60 mL of THF. To the system was added 200 mL (20 mmol) of 0.1M aqueous sodium hydroxide, and the reaction mixture was heated at 65 °C for 3h and was concentrated. The reaction mixture was concentrated with a rotary evaporator. To the system was added 400 mL of 6M aqueous hydrochloric acid, and the reaction mixture was heated at 110 °C for 15h under nitrogen. The reaction mixture was concentrated with a rotary evaporator, and the solid residue was dissolved in approximately 200 mL of water. This solution was brought of pH 7 with saturated aqueous sodium bicarbonate, and the resulting precipitate was collected by suction filtration, rinsed with water, ethanol and ether and dried in a vacuum oven at 40 °C to obtain 2.65g (63% yield) of (2',4'S)-(5)(R = o,p-difluorophenyl, R₁ = H) as a white solid, mp 231-234 °C. 1R (KBr): 1730, 1630cm⁻¹, ¹HNMR (DMSO-d₆): delta 0.90 (broad m,3H), 1.67 (m,2H), 3.5 (broad m,4H), 7.33 (m,1H), 7.61 (m,1H), 7.80 (m,1H), 7.80 (m,1H), 8.04 (d,1H,J = 14), 8.79, 8.81 (2s,1H).
 Anal. Calc'd. for C₂₀H₁₇F₃N₄O₃ · 1/4H₂O:
 C,56.80;H,4.17;N,13.25. Found: C,56.76;H,4.10,N,13.34.

Example 3Sulfuric Acid Salt of (2',4'S)-7-(4'-Amino-2'-methylpyrrolidin-1'-yl)-1-(o,p-difluorophenyl)-1,4-dihydro-6-fluoro-4-oxo-1,8-naphthyridine-3-Carboxylic Acid

Compound (2',4'S)-(5)(R = o,p-difluorophenyl, R₁ = H) was prepared as described in Example 2. In an Erlenmeyer flask were placed 247 mg (0.591 mmol) of (2',4'S)-(5)(R = o,p-difluorophenyl, R₁ = H) and 1.48 mL (0.295 mmol) of 0.2M aqueous sulfuric acid. The mixture was heated, and 25 mL of water was added to the system. The solution was hot-filtered, and the filtrate was freeze-dried to obtain 258 mg (93% yield) of (2',4'S)-(5)(R = o,p-difluorophenyl, R₁ = H) · 1/2H₂SO₄ as a white solid, mp >260 °C.

Example 4Hydrochloric Acid Salt of (2',4'S)-7-(4'-Amino-2'-methylpyrrolidin-1'-yl)-1,4-dihydro-1-(o,p-difluorophenyl)-6-fluoro-4-oxo-1,8-naphthyridine-3-carboxylic acid

Compound (2',4'S)-(5)(R = o,p-difluorophenyl, R₁ = H) was prepared as described in Example 2. In an Erlenmeyer flask were placed 240 mg (0.574 mmol) of (2',4'S)-(5)(R = o,p-difluorophenyl, R₁ = H) and 30 mL of 10% aqueous hydrochloric acid, and the mixture was heated to boiling. The solution was concentrated with a rotary evaporator. The residue was dissolved in ethanol, and ether was added to this solution. The resulting precipitate was collected by suction filtration to afford 219 mg (84% yield) of (2',4'S)-(5)(R = o,p-difluorophenyl, R₁ = H).HCL as an off-white solid, mp >260 °C.

Example 5

Hydrochloric Acid Salt of (2',4'S)-7-(4'-Amino-2'-methylpyrrolidin-1'-yl)-1,4-dihydro-6-fluoro-1-(p-fluorophenyl)-4-oxo-1,8-naphthyridine-3-carboxylic acid

(a) By replacing (2)(x=Cl,R=p,p-difluorophenyl, R₁=-CH₂CH₃) in Example 2a with (2) (x=Cl,R=p-fluorophenyl,R₁=-CH₂CH₃), one can obtain (2',4'S)-(4)(R=p-fluorophenyl,R₁=-CH₂CH₃).

(b) By replacing (2',4'S)-(4)(R=p,p-difluorophenyl,R₁=-CH₂CH₃) in Example 2b with (2',4'S)-(4)-(R=p-fluorophenyl,R₁=-CH₂CH₃) obtained in Example 2a, and replacing the neutralization portion of Example 2b with a recrystallization from 10% aqueous hydrochloric acid, one can obtain (2',4'S)-(5)(R=p-fluorophenyl,R₁=H)·HCL as a white solid. 1R (KBr): 1720, 1630cm⁻¹ ¹HNMR (DMSO-d₆): delta 0.98 (broad m,3H), 1.93 (m,1H), 2.18 (m,1H), 3.5-3.9 (m,4H), 7.43 (dd,2H, J=9,9), 7.70 (dd,2H,J=6,9), 8.15 (d,1H,J=14), 8.38 (broad, 2H), 8.68 (s,1H).

Example 6

(2',4'S)-7-(4'-Amino-2'-methylpyrrolidin-1'-yl)-1-(2,4-difluorophenyl)-1,4-dihydro-6-fluoro-4-oxo-quinoline-3-Carboxylic Acid

(a) In a round-bottom flask was placed 0.78 g (3.2 mmol) of (2S,4S)-4-acetamido-1-tert-butoxycarbonyl-2-methylpyrrolidine. To the system, at 0° C, was added 4.5 mL of trifluoroacetic acid. The cold bath was removed, and the solution was stirred at room temperature for 0.5 hour and concentrated with a rotary evaporator. The resulting oil was dissolved in 20 mL of methanol, and 3.8g of Rexyn 201 resin was added to the system. The mixture was stirred at room temperature for approximately 4 hours. During this period, an additional 3-4g of resin was added to the system. The mixture was filtered through a celite pad, and the filtrate was concentrated with a rotary evaporator to obtain a pale yellow oil. This material was used without further purification.

(b) Under a nitrogen atmosphere, in a 25 mL round-bottom flask were placed the (2S,4S)-4-acetamido-2-methylpyrrolidine obtained in part (a) and 1.5 mL of pyridine. To the system were added 1.28 g (3.5 mmol) of ethyl 6,7-difluoro-1-(2,4-difluorophenyl)-1,4-dihydro-4-oxo-quinoline-3-carboxylate and 0.49 mL (353 mg, 3.5 mmol) of triethylamine. The reaction mixture was heated at 65° C for 2 days and concentrated with a rotary evaporator. The crude material was subjected to flash column chromatography to obtain 1.03g of (2',4'S)-ethyl 7-(4'-amino-2'-methylpyrrolidin-1'-yl)-1-(2,4-difluorophenyl)-1,4-dihydro-6-fluoro-4-oxo-quinoline-3-carboxylic acid as a light yellow viscous oil which partially solidified under vacuum.

(c) Under a nitrogen atmosphere, in a 250 mL round-bottom flask were placed 1.02 g (2.09 mmol) of the material obtained in part (b) and 16 mL of THF. To the system was added 34.0 mL (3.4 mmol) of 0.1 M aqueous sodium hydroxide, and the solution was heated at 75° C for approximately 0.5 hour. The reaction mixture was concentrated with a rotary evaporator. To the system was added 42 mL of 6 M aqueous hydrochloric acid, and the reaction mixture was heated under nitrogen at 110° C for 12-13 hours. The temperature of the heating bath was increased to 118° C, 5 mL of 12 M aqueous hydrochloric acid was added to the system and the solution was heated for 2 hours. The reaction mixture was concentrated with a rotary evaporator, and the resulting yellow solid was dissolved in 1 M aqueous sodium hydroxide and extracted with several portions of chloroform. The aqueous solution was brought to pH7, and the resulting solid was collected by suction filtration. The solid was suspended in approximately 5 mL of ethanol, and the mixture was heated to boiling. The mixture was cooled in an ice bath, and the (2',4'S)-7-(4'-amino-2'-methylpyrrolidin-1'-yl)-1-(2,4-difluorophenyl)-1,4-dihydro-6-fluoro-4-oxo-quinoline-3-carboxylic acid (268 mg) was isolated as an off-white solid, mp 206-210° C. 1H NMR (DMSO-d₆): delta 0.99, 1.02 (2 overlapping d, 3H, J=6), 1.70 (m, 1H), 1.83 (m, 1H), 2.84-4.04 (complex, 4 H), 5.86 (m, 1H), 7.44 (m, 1H), 7.75 (m, 1H), 7.88 (d, 1H, J=15), 7.96 (m, 1H) 8.73, 8.77 (2s, 1H).

In Vitro Studies

The in vitro antibacterial activity of the test compound was determined by conventional agar dilution procedures. The organisms were grown overnight in brain-heart infusion (BHI) broth (Difco 0037-01-6) at 36° C. Twofold dilutions of the stock solution (2000 g/mL) of the test compound were made in BHI agar to obtain a test concentration ranging from 200 to 0.005 g/mL. The plate was inoculated with approximately 10⁴ organisms. It was then incubated at 36° C for 18 h. The minimal inhibitory concentration was the lowest concentration of the test compound that yielded no visible growth on the plate.

The results of in vitro testing are shown in Tables 1 and 2 below.

TABLE 1

In Vitro Data - Naphthyridines			
ORGANISM		MIC (MCG/ML)	
		Example 2	Example A*
S. aureus	CMX 730A	0.03	0.03
S. aureus	CMX 705	0.03	0.03
S. aureus	ATCC 25923	0.06	0.03
S. aureus	GYR 1162	0.03	0.03
E. faecalis	CMX 729G	0.25	0.25
E. faecalis	GYR 1166	0.5	0.5
S. agalactiae	CMX 508	0.12	0.12
S. pyogenes	M79061-98	0.25	0.25
E. coli	ATCC 25922	0.03	0.03
E. coli	CMX 733	0.03	0.03
E. coli	CMX 756	0.03	0.03
E. coli	CMX 744A	0.03	0.03
K. pneumoniae	CMX 724A	0.06	0.06
K. pneumoniae	CMX 735A	0.06	0.06
P. mirabilis	CMX 704F	0.25	0.25
P. mirabilis	CMX 729B	0.25	0.12
P. aeruginosa	CFS 387C	0.5	1
P. aeruginosa	CFS 350F	0.5	0.5
P. aeruginosa	CMX 719A	2	2
P. aeruginosa	A 5005	0.5	0.5
H. influenza	504	0.008	0.15
H. influenza	519A	0.008	0.15
H. influenza	566A	0.008	0.15
H. influenza	588A	0.008	0.008
N. gonorrhoeae	CMX 591	0.06	0.06
N. gonorrhoeae	35F AMPI	0.004	0.004
L. pneumophila	ATCC 33152	0.25	0.25
L. pneumophila	PHILA 2	0.25	0.25
L. bozemanni	ATCC 33217	0.25	0.5
B. fragilis	AT25285	0.5	0.4
B. fragilis	UC-2	0.5	0.8
C. difficile	ATCC 9689	1	1.6
C. difficile	ATCC 17857	1	0.8

7-(3-Amino-pyrrolidin-1-yl)-1-(2,4-difluorophenyl)-1,4-dihydro-6-fluoro-4-oxo-1,8-naphthyridine-3-carboxylic acid

TABLE 2

In Vitro Data - Quinolines				
			MIC(MCG/ML)	
			EX. B*	Ex. 6
	STAPHYLOCOCCUS	AUREUS	ATCC 6538P	.02
10	STAPHYLOCOCCUS	AUREUS	CMX 6868	.05
	STAPHYLOCOCCUS	AUREUS	A5177	.05
	STAPHYLOCOCCUS	AUREUS	45	.1
	STAPHYLOCOCCUS	AUREUS	45RAR2	.1
	STAPHYLOCOCCUS	AUREUS	CMX 503A	.05
15	STAPHYLOCOCCUS	AUREUS	CMX 553	.05
	STAPHYLOCOCCUS	EPIDERMIDIS	3519	.1
	MICROCOCCUS	LUTEUS	ATCC 9341	.39
	MICROCOCCUS	LUTEUS	ATCC 4698	.78
	ENTEROCOCCUS	FAECIUM	ATCC 8043	.2
20	STREPTOCOCCUS	BOVIS	A5196	.39
	STREPTOCOCCUS	AGALACTIRE	CMX 508	.2
	STREPTOCOCCUS	PYOGENES	EE561	.2
	STREPTOCOCCUS	PYOGENES	930 CONST	.1
25	ESCHERICHIA	COLI	JUHL	0.02
	ESCHERICHIA	COLI	SS	.002
	ESCHERICHIA	COLI	DC-2	.2
	ESCHERICHIA	COLI	H560	.02
	ESCHERICHIA	COLI	KNK 437	.2
30	KLEBSIELLA	PNEUMONIAE	ATCC 8045	.01
	PROVIDENCIA	STUARTII	CMX 640	1.56
	PSEUDOMONAS	AERUGINOSA	BMH10	.1
	PSEUDOMONAS	AERUGINOSA	A5007	.2
	PSEUDOMONAS	AERUGINOSA	K799/WT	.2
	PSEUDOMONAS	AERUGINOSA	K799/61	.05
35	PSEUDOMONAS	CEPACIA	296I	6.2
	ACINETOBACTER	SP	CMX 669	.05

*

7-(3-Amino-pyrrolidin-1-yl)-1-(2,4-difluorophenyl)-1,4-dihydro-6-fluoro-4-oxo-quinoline-3-carboxylic acid

Solubility Studies

A known excess weight of the compound was shaken overnight with a known volume of Ringer's buffer (bicarbonate buffer containing sodium, potassium, calcium and magnesium ions, initially adjusted to pH 7.5). The contents were filtered, and the clear filtrate was analyzed after appropriate dilution using HPLC (UV absorbance detection). The results of such solubility analysis is shown in Table 3.

TABLE 3

AQUEOUS SOLUBILITY (at pH 7.5 in Ringer's buffer)	
COMPOUND	SOLUBILITY (MG/ML)
Example A	0.008
Example 2	0.15
Epimer of Example 2	0.34
Example B	0.008
Example 6	0.053
Epimer of Example 6	0.182

The solubility data shown in Table 3 indicates that compounds 2 and 6 show significantly improved aqueous solubility properties compared with their respective 2-unsubstituted aminopyrrolidine analogs A and B.

Pharmacokinetic Studies

Mice were administered the quantity of compound indicated orally, as a single dose. At the specified time intervals, blood was collected from groups of five mice. All samples were assayed by a disk agar diffusion bioassay procedure. Bacillus subtilis 6633 or Klebsiella pneumoniae 10032 were used as the assay organisms, and seek agar medium No.1 (BBL Microbiology Systems; Cockeysville, MD) was the growth medium. The plates were incubated at 32 ° C for 18h and read with an image analyzer (Optomax Inc.). The results of such pharmacokinetic analysis are shown in Table 4.

TABLE 4

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COMPARATIVE PHARMACOKINETIC DATA

Compound	Oral Dose* (mg/kg)	Blood Level of Compound (ug/ml)						
		t(h)	0.5	1.0	2.0	3.0	6.0	24.0
¹⁰ Example 2	25		5.9	3.2	3.3	2.8	1.3	0.2
Example A	100		--	2.3	1.7	1.7	0.9	--
¹⁵ Example 6	25		3.7	4.3	2.8	1.1	0.1	0.0
Example B	100		--	0.5	0.7	0.9	0.7	0.0

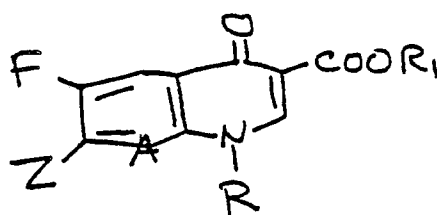
* Please note that Examples A and B were administered at 4 times the dose of Examples 2 and 6, yet Examples 2 and 6 still achieve better blood levels than their respective 2-unsubstituted pyrrolidinyl derivatives.

The pharmacokinetic data shown in Table 4 indicates that compounds 2 and 6 have greatly improved oral absorption properties when compared with their respective 2-unsubstituted aminopyrrolidine analogs A and B. Compounds 2 and 6 achieve higher serum concentrations when administered orally at 25 mg/kg than their respective 2-unsubstituted analogs A and B achieve when administered at 100 mg/kg.

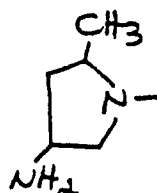
It will be understood that various changes and modifications can be made in the details of procedure, formulation and use without departing from the spirit of the invention, especially as defined in the following claims.

Claims

1. A compound having the formula:

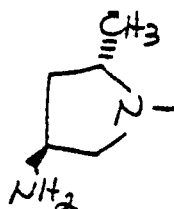


wherein A is CH or N; R₁ is hydrogen or a carboxy protecting group; R is selected from *o,p*-difluorophenyl or *p*-fluorophenyl; and Z is an amino group of the formula:



and pharmaceutically acceptable salts thereof.

2. A compound as defined in claim 1 wherein Z has the absolute stereostructural formula:



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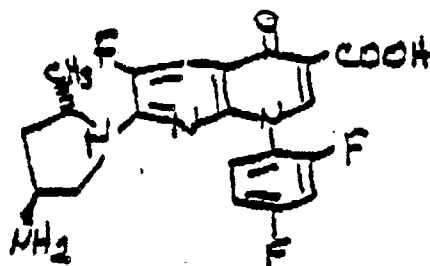
3. A compound as defined in claim 1 wherein R is *o,p*-difluorophenyl, Z is (2S,4S)-4-amino-2-methylpyrrolidin-1-yl and R₁ is hydrogen.

10 4. A compound as defined in claim 1 wherein R is *p*-fluorophenyl, Z is (2S,4S)-4-amino-2-methylpyrrolidin-1-yl and R₁ is hydrogen.

5. The compound having the formula

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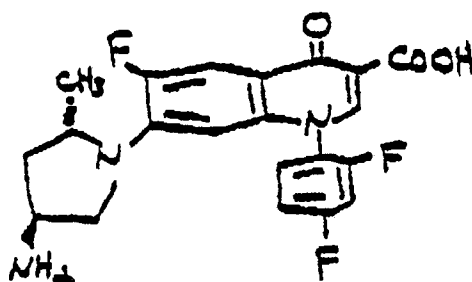
25 or pharmaceutically acceptable salts thereof.

6. The compound having the formula

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or pharmaceutically acceptable salts thereof.

40 7. A composition having antibacterial activity and improved solubility and pharmacokinetic profile in pharmaceutical dosage form containing a diluent and the compound as defined in Claim 1, 5 or 6.

8. Use of the compound as defined in Claim 1, 5 or 6 for preparing a drug useful in treating a bacterial infection in a patient.

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